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AUTHOR McCombs, Barbara L.: Dobrovolny, Jacqueline L.
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ABSTRACT

In the area of aptitude-treatment interaction (ATI) research, an outcome variable which has received relatively little attention is differential student learning times, or students' relative learning efficiency on one treatment as opposed to another. Although it has been argued that learning times are not appropriate variables for evaluating treatment effectiveness, the case may be made that (a) learning times are appropriate ATI outcome variables to examine in the increasing number of self-paced, criterion-referenced, and computer-based instructional environments: and (b) the study of differential learning time outcomes from treatments implemented in these self-paced environments can help advance our understanding of treatment component/learning strategy matches that contribute to increased learning efficiency. To determine the validity of this claim, generalizations from a number of ATI studies conducted in the context of the Air Force Advanced Instructional System are discussed. (Author/GSK)

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Times-to-Criterion: An Appropriate Outcome Variable for ATI Studies?

by

Barbara L. McCombs and Jacqueline L. Dobrovolny

McDonnell Douglas Astronautics Company - St. Louis

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In the area of ATI research, an outcome variable which has received relatively little attention is differential student learning times, or students' relative learning efficiency on one treatment as opposed to another. Although it has been argued that learning times are not appropriate variables for evaluating treatment effectiveness, the case can be made that (a) learning times are appropriate ATI outcome variables to examine in the increasing number of self-paced, criterion-referenced, and computer-based instructional environments; and (b) the study of differential learning time outcomes from treatments implemented in these self-paced environments can help advance our understanding of treatment component/learning strategy matches that contribute to increased learning efficiency. To determine the validity of this claim, generalizations from a number of ATI studies conducted in the context of the Air Force Advanced Instructional System are discussed.

Times-to-Criterion: An Appropriate Outcome Variable for ATI Studies?

Barbara L. McCombs and Jacqueline L. Dobrovolny

McDonnell Douglas Astronautics Company - St. Louis

For those of us working in the arena of applied educational research, translating theory into practice is both frustrating and exciting. On the frustrating side of the coin, methodological advances often lag conceptual ones, making theoretical applications risky and difficult. This is particularly true in the case of applying theoretical principles underlying aptitude-treatment interaction (ATI) research. On the exciting side of the coin, however, are the promises of more adaptive and effective instruction as a result of using ATI research designs in applied instructional settings--not to mention the possibility of further advancing our understanding of individual differences important to learning.

The specific problem being addressed here is the appropriateness of using times-to-criterion as an outcome variable in applied ATI research. That is, can applied ATI findings, where learning times were used as outcome variables, assist in (a) adapting instruction to individual differences and (b) advancing our understanding of individual differences? In order to assess the appropriateness of learning times as outcome variables in this context, we will first discuss various philosophical, theoretical, and methodological issues related to the problem area. This will be followed by an examination of ATI findings from a number of studies conducted in the context of the Air Force Advanced Instructional System (AIS)--a self-paced, criterion-referenced, and computer-based instructional environment. Specifically, in the examination of these applied ATI findings, we will be exploring the question of whether

differential learning time/student characteristic relationships can tell us anything about efficient student learning strategies with particular kinds of treatments or treatment components. Finally, we will discuss some remaining issues to be considered when learning times are used as ATI outcome variables.

Issues Surrounding the Problem Area

Philosophical Issues. The major philosophical issue related to the appropriateness of learning times as outcome variables in ATI studies has to do with the purpose of basic versus applied research. Although many researchers agree that the distinction between these two research areas is becoming increasingly blurred (e.g., Gehlbach, 1979, Glaser, 1979; Glass, 1979), Kerlinger (1977) has made a very convincing case for maintaining the distinction between these two research areas. Essentially, Kerlinger has argued that the primary purpose of basic research is to develop theory--to understand and explain phenomena, to explicate variables and their relationships. Applied research, on the other hand, has the purpose of achieving practical objectives and finding solutions to practical problems. The applied researcher, then, uses the theoretical explanations and understandings derived from basic research in making practical decisions about what will work best in a particular applied situation. The primary mission of the applied researcher is not to develop theories, although advancements in theory often result from the kind of problem solving required by applied research (Glaser, 1979; Kerlinger, 1977).

The relevance of this philosophical issue in determining whether learn-

ing times are appropriate ATI outcome variables in the applied setting becomes apparent when one considers the different goals of ATI research in applied versus basic settings. In the basic research setting, a major goal of ATI research is to develop a theory of individual differences, to understand the interactions between various individual difference characteristics and processes and various treatment characteristics and components. For example, if it can be determined, as Salomon (1979a, 1979b) suggests, that media symbol system characteristics or coding elements relate in specific ways to the activation of particular information processing skills, theory is advanced. In the applied research setting, one major goal of ATI research is the use of available theory in the search for treatments which will maximize learning outcomes for each individual student. Thus, for example, theorized media symbol system/student characteristic relationships might be applied in the form of alternative instructional treatments and/or adaptive decision rules for assigning these alternative treatments.

The point is that, accepting Kerlinger's (1977) position on the need to maintain the distinction between basic and applied research, what is appropriate in the area of applied research is of necessity judged on the basis of utilitarian and cost/benefit considerations. That is, do certain applied practices result in improved instructional procedures or outcomes as measured by gains in student performance, motivation, etc.? And, secondarily, do these applied practices assist in advancing instructional theory--either by enhancing it, expanding it, or even correcting it?

Theoretical Issues. Many educational researchers are currently decrying

the state of theory building in education and instruction. Opinions appear to be mixed as to whether we can or should be in the business of theorizing in educational research. For example, Scriven (1979) says that theoretical models are not appropriate for educational research, Suppes (1979) says that theory has a definite place in educational research, and Glass (1979) says that whatever theorizing we do must be done with a recognition of the conditions of high uncertainty under which educational researchers must operate. The situation appears to be particularly grim in the area of individual differences and instructional theory, with the recognition that although individual differences in aptitude can both predict learning outcomes and interact with variations in instructional treatments, many interactions are so complex that generalizations and theory building become almost impossible (e.g., Cronbach, 1975; Cronbach & Snow, 1977; Gehlbach, 1979; Snow, 1977).

But is the situation really so grim--what is the state of theory building in the area of individual differences and ATI research? Is there anything that we applied researchers can get a handle on in solving problems of how to provide effective individualized instruction? Our more optimistic colleagues (e.g., Glaser, 1979; Snow, 1977; Wittrock, 1978) point out the rapid advancements in our understanding of individual differences that have arisen out of the theoretical framework of modern cognitive psychology, or a cognitive psychology of information processing. Advancements are being made in theories of individual difference measurement, cognitive functions and skills related to learning under varying instructional conditions, as well as in our understanding of how com-

prehension and knowledge acquisition take place. We now see the learner as actively constructing knowledge by the use (or misuse) of a wide variety of learning strategies, processes, and skills that can be deliberately, incidentally, or accidentally acquired. We also know that accommodation to individual differences can occur by modifying the instructional treatment (including the method of instruction, the media of instruction, the conditions of instruction, or the instructional situation) or by modifying the student's characteristics (including the modification of the student's learning strategies, processes, and skills).

What is less well known at this point in time are the most effective instructional strategies, treatments, and skill training approaches to use in adapting to individual differences for various student populations and instructional contents and situations. It is here that pessimism, such as that expressed by Snow (1977) and later by Gehlbach (1979) can be easily understood. Although Snow (1977) believes that a theory of individual differences is possible, he sees that the state of affairs in ATI research makes general theory impossible, leaving only the possibility of specific theories that are limited in both time and place. Only at some future time does Snow believe that local theories might be categorized to arrive at more general instructional theory, and this must await the time when aptitudes themselves are more thoroughly understood. Gehlbach (1979) agrees that local theories are all that can be hoped for at the present stage of ATI research, but argues that the cost in time and money of developing these local theories and their eventual payoff in instructional practice may not be worth it.

This pessimism notwithstanding, the fact remains that a number of researchers are reporting sizeable relationships between various aptitude and criterion variables under differential treatment conditions (cf., e.g., Cronbach & Snow, 1977). In addition, theoretical advancements continue to be made, for example Salomon's (1979a, 1979b) recent work on the interaction of media, cognition, and learning. In describing various theoretical considerations of how media symbol systems relate to cognition and learning, Salomon clarifies the concept that not only does a medium do something to the learner, but the learner does something with the medium. The implications of this are that we can begin to analyze various ATI research findings--whether they be from basic or applied domains--in terms of the reciprocal effects treatment components are having on the activation or supplantation of various learner processes and skills. And we can go a step further and hypothesize what these reciprocal effects may mean in terms of a learner's use of various learning strategies and how we can motivate or induce or instruct the learner to use more effective and efficient strategies.

The question is, however, what can current theory tell us about the appropriateness of learning time as an ATI outcome variable--a variable that, in the applied setting, can be examined to expand or enhance our understanding of effective treatment component/student characteristic or learning strategy matches? In this regard, Carroll's (1963) model of school learning--subsequently adopted by Keller (1968) in his model of personalized instruction and transformed by Bloom (1974) into a mastery learning model--holds that time to learn or learning rate is the variable

of primary concern in school learning and the chief source of individual differences in what or how much students learn. Critics of this model are more concerned with the methodological appropriateness of learning times as a reflection of individual differences in student aptitudes (c.f., Cronbach & Snow, 1977). They are less concerned with the conceptual appropriateness of learning times as important outcome variables in the growing number of mastery-based, self-paced instructional environments where time-to-learn has practical cost implications (such as in vocational training or military technical training). The methodological concerns are the topic of the next section.

Methodological Issues. In evaluating the methodological problems involved with using learning times in ATI studies, summarized by Cronbach and Snow (1977), it is important to keep in mind the issues we've just discussed: (a) the difference in research purpose between basic and applied ATI research (i.e., theory building versus solving practical problems), (b) theoretical advances that can assist in analyses and interpretation of ATI findings (i.e., concepts of the active role the learner plays in learning and the value of studying reciprocal learner characteristic/treatment component relationships), and (c) the apparent validity of learning time as an outcome variable in certain applied environments (i.e., the conceptual appropriateness of learning times as outcomes of primary concern in mastery-based, self-paced instructional environments).

The primary methodological issues surrounding the use of learning times as ATI outcome variables, as discussed by Cronbach and Snow (1977), can be categorized into three major problem areas. First, there is the problem

of learning rate fluctuations over time due to a variety of student or environmental (internal or external) reasons. These fluctuations contribute to error, making the measurement of "true" learning rate difficult and successive observations of a student's learning rate necessary. Second, depending on how one both defines and measures student attainment of a criterion, one faces the problem of obtaining different learning rate outcomes. That is, learning (or change in student performance) is multivariate, and a student can conceivably reach criterion on different variables at different times, making evaluations of learning time outcomes difficult. Finally, there is a set of problems related to learning-to-learn (e.g., not controlling for this phenomena).

Now let's examine these methodological concerns in the context of applied ATI studies conducted in a mastery-based, self-paced environment where learning times are the most meaningful and practical outcome to consider in adaptation to individual differences. It is a well known fact to all researchers working in such environments that, because of lack of sufficient experimental controls, large sources of error variance can be expected in almost any variable of interest, and particularly in the criterion variable. It has been our experience, however, that if one can establish reasonably adequate procedural controls in the classroom, there is no reason to expect larger sources of error variance in learning times (times-to-criterion) than in criterion test scores, particularly when criterion tests are developed by course personnel and not the experimenter (e.g., McCombs, 1979; McCombs & McDaniel, 1978). In fact, in several studies (Judd, McCombs, & Dobrovolny, 1979; McCombs, Dobrovolny, & Judd,

1979) we were able to obtain substantially higher and more reliable learning time/predictor relationships over a period of time following instructional system implementation than criterion test score/predictor relationships. That is not to say that in a basic research study this situation would be true, or for that matter that this would be true in studies with well-developed criterion measures. But the fact is, in applied settings such as we were working with (individualized, self-paced, computer-based instruction), this is a common situation. Support for this claim can be found in a recent applied study by Gettinger and White (1979) in which it was found that for fourth, fifth, and sixth grade boys and girls, time to mastery was more highly correlated with achievement on six learning tasks than was a measure of intelligence.

The other problems discussed by Cronbach and Snow (1977), (a) the multivariate nature of student performance and the fact that different learning rate outcomes can be obtained with different criterion variables and (b) controlling for learning-to-learn to avoid adverse effects on predictor/outcome relationships, are troublesome. Because of the difference in purpose for applied versus basic research, however, these problems are of less concern. That is, however arbitrary, criterion levels are defined by practical, applied considerations and the ATI researcher must live with these in trying to maximize student performance through individualization. The learning-to-learn problem is usually less severe in applied environments in that treatments are generally of longer duration than in most basic or laboratory studies, and the number of students available for analysis is generally substantially larger. So, the question remains of whether ATI

findings from an applied setting can contribute to our increased understanding of effective student characteristic/treatment component/learning strategies matches or to solving the problem of effective adaptation to individual differences. To answer this question, generalizations from a number of ATI studies conducted in the context of the AIS are discussed in the following section.

Example from the Advanced Instructional System

Description of Applied Research Context. The applied ATI research context was the Air Force Advanced Instructional System, or AIS. The AIS is a multi-media, computer-based instructional system designed to improve the effectiveness and efficiency of Air Force technical training and to provide an operational research facility for assessing innovations in instructional technology. The AIS currently supports two technical training courses (with an average total student population of approximately 800 male and female trainees) representative of the range of cognitive and performance skills required by enlisted Air Force personnel. An adaptive instructional decision model employs state-of-the-art computer software, statistical methodologies, and instructional procedures to provide instructional management and individualized assignments to alternative instructional materials.

Each AIS course is divided into "blocks" of instruction which may require anywhere from one to 15 days to complete. Each block contains a number of lessons and a comprehensive, end-of-block criterion test. Within a block, lessons are arranged in a hierarchy based on their prerequisite relationships and lessons are the basic unit of instruction. Each lesson

consists of a set of objectives, two or more forms of a criterion test, and typically, a self-test by which students can evaluate their understanding of the lesson before taking the criterion test. A lesson's instruction is provided by one or more modules, each of which teach the same lesson objectives and cover the same lesson content. Where two or more modules are present, they represent alternative instructional treatments or strategies.

Alternative instructional treatments, or modules, were designed to differ in two basic ways. The first class of alternative modules, termed multi-tracked modules, were designed on the basis of available theory and technical judgement to adapt to specific empirically assessed student differences by varying some combination of instructional parameters such as format or structure (e.g., placement of embedded questions or reviews), media (e.g., use of audio versus print or visual versus verbal organizers), or comprehension aids (e.g., presence or absence of explanatory feedback or functional descriptions). The second, simpler class of alternative modules, termed media overlap modules, were designed to answer the question of whether varying only the instructional medium (e.g., programmed text versus sound/slide or illustrated text) provided adequate adaptation to individual differences. Thus, the multi-tracked alternatives were those systematically designed to adapt to specific kinds of individual differences, while media overlap alternatives were the result of simply providing the same content and strategies in an alternative medium.

The question of alternative treatment effectiveness was evaluated under two major instructional conditions for both multi-tracked and media

overlap alternatives. That is, treatments were evaluated in the absence and presence of the AIS Student Progress Management Component (SPMC). The SPMC generates target course completion times for each student. These targets are predicted on the basis of the student's abilities, attitudes, interests, and background information as measured by a battery of tests given all students prior to course entry. The AIS generates a printout of target times for each block and the student's total course completion time, listed in units of days and tenths of days. This printout is delivered to the student and the student's learning center instructor when a student enters the course. The information from the printout is used (a) by the student in tracking his or her performance (progress) in the course relative to predicted progress and (b) by the instructor in monitoring whether students are ahead or behind schedule. If a student falls behind schedule, and the schedule is determined to be a reasonable one, it is the student's responsibility to get back on schedule within a contracted (with the instructor) period of time. Thus, whereas in the no progress management condition, students can, practically speaking, progress through the course at their own rate, in the progress management condition, a number of external constraints are imposed on the student's rate of progress through the course.

Thus, the basic experimental design in this analysis consisted of the evaluation of ATI outcomes (learning times, criterion test scores) for two types of adaptive treatments (multi-track, media overlap), within two instructional conditions (no progress management, progress management). This ATI study reduces to a two-by-two design, with two classes of in-

dependent variables (treatments, conditions). These independent variables each have two levels and are examined for two criterion variables.

Application of ATI Research Theory and Methodology. In deriving procedures to be used in the development and implementation of alternative treatments in the AIS, as much reliance as possible was placed on available ATI research theory and methodology. The resulting set of procedures (described in detail by McCombs & McDaniel, 1978, and Parkhurst & McCombs, 1979) basically consisted of those steps shown in Figure 1 (from Parkhurst & McCombs, 1979). This methodology involves six main steps labeled Points A through J in Figure 1.

Step 1: (Point "A") Establish main track modules. Establish a single or main track of instruction; that is, develop a "best guess" approach or strategy for teaching instructional concepts (grouped into modules) for the entire course or unit being taught.

Step 2: (Point "B") Establish student characteristics data pool. Establish a data pool of cognitive and affective student characteristic variables of interest and importance. These variables are ones that are expected, on the basis of available literature and technical judgement, to be closely associated with performance on the criterion measures and can be easily assessed by available or developed measures.

Step 3: (Point "C") Assess main track module performance. Examine the dependent variables of interest, both criterion test scores and completion times, with regard to student failure rates or amount of variance in student performance on the main track of instruction. Identify those main track modules with high failure rates or excessive variance in the

dependent variables and label these modules "unacceptable."

Step 4: (Points "D" and "E") Analyze predictor/criterion variable relationships. Analyze predictor/criterion variable data and, based on significant predictor/criterion relationships, design and develop alternative modules for selected unacceptable main track modules.

Step 5: (Points "F", "G", and "H") Evaluate alternative module(s). Implement alternative module(s) and evaluate their effectiveness in meeting the needs of the students for whom they were designed. That is, examine the performance of students randomly assigned to main track and alternative modules via an ATI regression analysis approach, using the most predictive aptitude variables in the treatment design set. Assess evaluation results and make decisions as to the relative effectiveness of the alternative module(s) versus main track modules.

Step 6: (Points "I" and "J") Individualize the assignment of alternative modules. For those alternative modules that demonstrated satisfactory performance in meeting differential student needs, devise assignment rules for computer-based (adaptive decision model) selection of student/module matches. Continue to monitor and evaluate the performance of alternative module(s).

INSERT FIGURE 1 ABOUT HERE

These six basic steps were used in applying ATI research theory and methodology in the AIS. Individual difference or aptitude variables were selected on the basis of available theory and included both cognitive and

affective student characteristics. From the total set of preassessment variables, the cognitive variables relevant to this study were (1) two measures of students' comprehension of printed passages extracted from course technical manuals, which represented course-specific measures of students' pre-course familiarity with or comprehension of technical materials; (2) a rote memory measure on which the student's task was to memorize digit series or course-related alphanumeric series; and (3) a higher order memory ability measure on which the student's task was to remember a series of numbers or course-related alphanumerics in an order backwards from the presentation order. Affective variables included (1) measures of generalized trait anxiety, state anxiety toward learning the course materials, and anxiety about taking tests; and (2) measures of generalized trait curiosity and state curiosity toward learning the course materials.

These cognitive and affective variables were found to be most predictive (of those total number of variables measured at the beginning of the course) of student performance (learning times, scores) on the original maintrack lessons selected for discussion here, and were the design variables for the multi-tracked alternative modules for these lessons. These variables were also predictive of student performance (learning times, scores) on the media overlap modules of interest. The following section briefly describes the lessons or learning tasks and the types of alternative modules used in the summary of AIS ATI findings.

ATI Summary Tasks and Procedures. In order to assess contributions of ATI findings which included times-to-criterion as outcome variables, four

lessons with similar alternative treatments (for both the multi-tracked and media overlap classes of alternative modules) were selected for analysis. These four lessons were part of the Inventory Management (IM) course, a curriculum which teaches clerical-type skills and enrolls male and female students with a wide variety of cognitive and affective characteristics.

Multi-tracked treatments consisted of a basic programmed text main track module for each of the four lessons and two enriched alternative modules. The enriched modules expanded on the basic programmed text and included (a) explanatory feedback to embedded questions in the programmed text; (b) organizational aids in the form of visual or verbal organizers of important concepts in the lessons; (c) functional visuals and examples of new procedures or concepts to be learned; and (d) a variety of alternative presentation media to the main track programmed text, including sound/slide audio-visual programs, color illustrated texts with and without audio tapes, and black and white illustrated scripts.

Specifically, as shown in Figure 2, the experimental design summarized students' learning times and criterion test scores across four lessons for (a) basic (main track) versus enriched (alternative) multi-track treatments, and (b) audio-visual versus illustrated script media overlap treatments. The media overlap comparisons consisted of summarizing student performance on the two enriched treatments, where only the media differed. All treatment results were summarized across progress management conditions, and results which were a function of progress management condition were noted. Data available for the ATI analyses ranged from 34 to 168 students

per alternative module and instructional condition, with an average of 86 students per alternative module (or experimental cell).

INSERT FIGURE 2 ABOUT HERE

The procedures used in summarizing ATI findings for these two classes of adaptive treatments across the four lessons generally consisted of the following steps: (1) ATI regression analyses for each lesson were calculated separately for each cognitive and affective predictor variable, criterion variable (times-to-criterion and criterion test scores), and instructional condition (no progress management and progress management); (2) the resulting significant ATI findings per lesson, type of treatment comparison (multi-track, media overlap), predictor variable, criterion variable, and instructional condition were annotated within treatment class; (3) consistencies in the patterns of findings for students scoring best with each treatment and their location at predictor variable extremes (low, high) across criterion variables and instructional conditions were identified; and (4) findings which were consistent within a particular criterion variable or instructional condition were identified. Consistency was defined on the basis of whether, out of the total number of significant ATIs with a particular predictor variable within a treatment class, the majority of findings were in the same direction.

It was expected that consistent findings would be useful in determining whether these ATIs (a) helped explain student characteristic/treatment component/learning strategy matches or (b) could form a meaningful basis for adaptation decisions and instructional design decisions. It was

expected that inconsistent findings would help elucidate the (a) independent contributions of learning times versus criterion scores and (b) relationship of learning time/predictor findings to types of progress management condition, as well as contribute to our understandings of individual differences and adaptive decision making. The results of these ATI data summaries are described in the following section.

Description of ATI Summary Results. We first evaluated (a) the average correlation between predictor variables and criterion variables and (b) the average correlation between the two criterion variables of interest in these ATI studies (times-to-criterion, criterion test scores). The correlations between predictor and criterion variables were examined to determine if the magnitude of these relationships is theoretically or practically meaningful for both criterion variables. The correlations between the two criterion variables were examined to assess the similarity of these two criterion variables in terms of assessing learning outcomes and whether they are making independent or joint contributions to the explanation of student characteristic/treatment component/learning strategy matches.

In general, (a) predictor/learning times correlations were slightly higher than predictor/scores correlations (.39 versus .34 on the average); (b) cognitive and affective predictors were related to criterion variables at about the same level (.38 versus .36 on the average); and (c) predictor/criterion relationships were about the same for learning times in the progress management condition compared to the no progress management condition (.40 versus .38 on the average), while for criterion test scores, correlations with predictor variables were somewhat higher in the no

progress management than management condition (.37 versus .31 on the average).

The correlations between times-to-criterion and criterion test scores across the alternative treatments for the four lessons ranged from (a) -.25 to -.69 in the no progress management condition and (b) -.33 to -.72 in the progress management condition. The average correlation between times-to-criterion and criterion test scores was slightly higher in the management condition (r = -.51) as compared to no management condition (r = -.46).

Table 1 summarizes the AIS ATI data. As can be seen, for ATI's representing treatment differences collapsed across media (top of Table 1) and across both management conditions, students who performed best in terms of both times and scores, with the main track (programmed text) lessons, generally scored high on the two reading comprehension measures and low on the trait and test anxiety measures. An exception to this general trend, however, was the learning time ATI findings under the no management condition. That is, when students were free to pace themselves, those high in trait anxiety were most efficient (completed in less time) when given the main track as opposed to the enriched treatment.

INSERT TABLE 1 ABOUT HERE

Comparing the main track treatment with that of the enriched treatments (audio-visual, AV, and illustrated script, IS) across both management conditions, it was found that students who generally performed best on the enriched treatments scored low on the two reading comprehension measures and

high on the trait and test anxiety measures. Again, however, under the no management condition, there was a reversal in the learning time ATIs, with students low in trait anxiety completing the enriched lessons most quickly.

When the management/no management conditions of the main track and enriched treatments were compared, there were several consistent ATIs with trait and state curiosity, across learning tasks and criterion variables, which differed as a function of the particular management condition. That is, students who performed best on the main track treatments under the no management condition were low in trait curiosity, whereas students who performed best on this main track treatment under the management condition scored high on both the trait curiosity and the state curiosity measures. Similarly, students who did better on the enriched treatments under the no management condition were high in trait curiosity, whereas the students who performed best on these enriched treatments under management were low in both trait and state curiosity.

The lower portion of Table 1 summarizes the ATI data for treatments where only the media differed (i.e., comparison of the AV and IS enriched treatments). As can be seen, across both management conditions, students who generally performed best with the AV treatment scored high on the reading comprehension measures, the rote memory measure, and the state anxiety measure. On the other hand, students who generally performed best with the IS treatment scored low on the reading comprehension measures, the rote memory measures, and the state anxiety measure. As Table 1 indicates, there were some inconsistencies in the learning time ATIs. Basically, the learning time ATIs indicated that low rote memory ability students performed

most efficiently under both management and no management conditions with the AV treatment for one of the learning tasks.

In examining the ATI finding differences for the AV and IS treatments associated with management conditions, it was found that students who performed best with the AV treatment were low in trait anxiety, and high in both trait and state curiosity. Students who performed best with the AV treatment under the no management condition were high in trait anxiety and low in trait curiosity, state curiosity, and higher order memory skills. With respect to the IS treatment, students who performed best with this treatment under no management were those who scored low on the trait anxiety measure, high on the trait and state curiosity measures, and high on the higher order memory measure. Finally, students who performed best with the IS treatment under management were those who scored high on the trait anxiety measure and low on both the trait and state curiosity measures. As can be seen in the lower part of Table 1, the higher order memory measure only became a significant predictor of student performance with differing treatments under the management condition.

Theoretical Speculations on ATI Summary Results. These findings have numerous implications for learning theory. First, in looking across management conditions at the comparison of student performance on the main track versus enriched treatments, the data indicate that the enriched treatments compensated for students who were poor readers and experienced high test and trait anxiety. On the other hand, high ability students who experienced little anxiety could perform well with a programmed text which did not

include such aids as explanatory feedback or organizational visuals. This speculation is in keeping with Salomon's (1979a, 1979b) position that treatment components may activate various skills or learning strategies developed by high ability students. We can further hypothesize that this activation process was facilitated for those high ability students whose skills were not blocked by high levels of anxiety.

In studying the exception to this general trend--the learning time ATI findings that when students were free to pace themselves (in the no management condition), those students who were high in trait anxiety were most efficient when given the main track as opposed to the enriched treatments--it can be speculated that students experiencing a great deal of constant anxiety (high levels of A-Trait) have developed numerous sophisticated strategies for coping with this anxiety. This speculation is in keeping with the work of Spielberger (1977), who posits that frequent encounters with stressful situations may cause anxious individuals to develop specific coping responses. Working within this framework, we can say that the high trait anxious students are capable of coping with the more difficult main track treatment under the no management condition--a condition which provides them with the time to implement their coping strategies. Under the management condition, however, these high trait anxious students have less time to implement their coping strategies and cannot perform as efficiently with the difficult main track treatment, regardless of the fact that they are of higher ability than students performing well with the enriched treatments. Thus, we can begin to see some generalizations

possible from the complex interaction of treatments, situations, learning strategies, and cognitive and affective aptitudes--even though these generalizations may be limited in time and place (c.f., Snow, 1977).

The management/no management student performance differences on the main track and enriched treatments were such that students who performed best on the maintrack treatments under management and on the enriched treatments under no management were high in trait curiosity. Additionally, students who performed best on the main track treatment under management were also high in state curiosity. This seems to imply that students who are generally interested in the world around them, and specifically interested in learning information in their course area, indulge their curiosity when there are no time limits, and thus seem to benefit from the enriched treatments. When these same kinds of students are given time limits, however, they need a brief and succinct treatment in order to perform well. That is, being specifically or epistemologically curious in the sense discussed by Berlyne (1967) and Day (1969) allows students to be more efficient and effective in the less enriched or main track treatment when time pressures are present. One obvious implication is that more motivational processes are necessary to perform well in this more arousing instructional treatment, while only a general level of positive motivation is necessary for students to perform well with the enriched treatments when there are no time pressures. Combining these speculations with the findings that were consistent across management conditions, we see that the positive motivational processes of trait and state curiosity

are acting in a complementary fashion with high ability and low levels of negative motivation (trait and test anxiety) in forming a more complete picture of the kind of student that performs best with more basic versus enriched instructional treatments under different instructional conditions (See Table 1). All of which is to say that findings of this type are helpful in theorizing about the effects of various instructional conditions on certain basic positive motivational processes.

The ATI findings across both management conditions for treatments where only the media differed, indicated that low ability students performed best with the printed illustrated script treatment, whereas the audio-visual treatment appeared to be substantially more difficult and was most effective for "good" students (high reading and memory ability) who were nervous about the course and perhaps more motivated to put their reading and memory skills to work. The exception to this general finding indicated that students with poor rote memory skills performed most efficiently with the audio-visual treatment on one of the four learning tasks, regardless of management condition. This suggests not only is the time criteria sensitive to task demand differences affecting the rote memory ability/treatment ATI, but also suggests that for students with poor rote memory skills, the specific demands of the task need to be accounted for before the type of media is selected. In other words, it would appear that the task on which students with poor rote memory skills performed most efficiently with the audio-visual treatment was a task which was significantly different from the other tasks on which the same

type of students performed best with the illustrated script treatment.

There are several characteristics of the alternative media to be considered in deriving theoretical implications from these ATI findings. For example, a unique quality of the audio-visual treatment requires the simultaneous processing and coding of both visual and auditory information. On the other hand, the illustrated script treatment requires consecutive processing and coding of visual and printed information. It is possible, therefore, that students with high skill mastery levels found the qualities of the audio-visual treatment to be more analogous to their own internal representations, while the illustrated script treatment supplanted many of these skill requirements and became a compensatory treatment for lower ability students. It would seem, therefore, that the audio-visual treatments used in this study activated student skills, whereas the illustrated script treatment supplanted or compensated for the lack of strong memory and reading skills (c.f., Salomon, 1979b).

Another media characteristic effecting theoretical implications is the fact that in this study the audio-visual treatment was program paced, while the illustrated script treatment allowed students to skip, review, reread sections, etc., as they wished. We can speculate, then, that to perform well with the audio-visual treatment, students had to be willing to give up some control of the learning process and place trust in their own learning ability and the teaching ability of the medium. It can also be hypothesized that since the audio-visual treatment presented information to the student via auditory and visual channels simultaneously, as well as

represented a potentially more novel and complex stimulus situation, it created a higher state of arousal (in the sense discussed by Berlyne, 1967) than did the illustrated script treatment. Thus, in order to perform well with the audio-visual treatment, students needed to have well-mastered cognitive skills, and also to be particularly adept at handling elevated states of arousal. Furthermore, it could be hypothesized that students high in state anxiety performed best with the audio-visual treatment because they were more capable of coping with the elevated states of arousal created by that treatment.

In comparing the audio-visual with the illustrated script treatments under the two different management conditions, it was found that students who performed well with the audio-visual treatment under the no management condition were relatively low in state and trait curiosity and high in trait anxiety, as compared to students performing well with the illustrated script treatment under no management. In addition, students with strong higher order memory skills performed better with the illustrated script treatment under no management as compared to students performing well with the audio-visual treatment under the same management condition. And furthermore, all these relationships were consistently reversed across the learning tasks when students were under the management condition. Such a finding supports Salomon's (1979a, 1979b) thesis that instructional situations are critical variables in evoking student abilities, aptitudes, and mental skills. That is, the demands of the no management condition were significantly different from the demands of the management condition and thus, one could

expect to find differences in the characteristics of students performing well in each condition. Moreover, the characteristic differences between students performing well in these two situations would intuitively seem to reflect differences in coping with different levels of arousal. One would expect, therefore, that the demands of the management condition would be such that in order to perform well, students would have to possess highly developed skills and strategies for coping with anxiety ("I have to finish this lesson today in order to stay on schedule.") or other high states of arousal. In the no management condition, however, one would expect that students who perform well would be faced with fewer anxiety arousing situational factors and would have to generate their own interest or curiosity about the course material so as to remain motivated enough to efficiently complete the course.

To sum up, this example of findings from applied ATI research allows us to make several general statements in addition to the specific theorizing presented above. First, we can see that if learning time and criterion score data are collected on similar treatments across several lessons or learning tasks in a course of instruction, these ATI findings can be summarized for the purpose of searching for consistent findings. Once consistencies can be demonstrated across these criterion variables of interest, or instructional conditions, we can begin to draw a profile of the kinds of students that perform best with certain kinds of instructional treatments. We can get a picture of the higher order interactions representative of the complexity of individual difference relationships. We can also use the ATI findings with both learning times and criterion scores

to draw some generalizations helpful to instructional design and instructional theorizing. Furthermore, by summarizing ATI findings across highly correlated criterion variables--in this case times-to-criterion and criterion test scores--we can begin to gain an understanding of student behavior patterns or learning outcomes as a function of certain instructional strategies or conditions. And because the findings were consistent, we can place more confidence in them than might be the case for other types of applied ATI studies--e.g., those of shorter duration or involving only a single criterion variable. Finally, examining the inconsistencies in criterion variable or instructional condition ATI findings can help us gain insights into factors responsible for these inconsistencies--factors which may reside in the learners or in the instructional situation.

General Discussion and Conclusions

In this final section, we go back to our original question: Are times-to-criterion an appropriate outcome variable for ATI studies? What answers have we provided to this question and what issues may remain in providing a more definitive or thorough answer? To examine these questions, let's review some of the points we have raised and addressed in this paper.

First, we stated that the question of the appropriateness of learning times as ATI outcome variables had to consider the research context, and specifically, whether the research was conducted in a basic versus applied setting. We agreed with Kerlinger's (1977) argument about the necessity and advantages of keeping the definition and goals of basic versus applied research distinct. Furthermore, we argued that in the case of ATI research,

this distinction between basic and applied research should be kept in mind both conceptually and methodologically. When Cronbach & Snow's (1977) methodological issues surrounding the use of learning times in ATI research were discussed, we concluded that when the concern is with the practical goal of adapting to individual differences in an applied instructional situation, and secondarily, with the goal of advancing instructional theory, these methodological issues are not critical.

We specifically addressed the appropriateness of using learning times in applied ATI research by presenting an example of a study conducted in the context of the Air Force Advanced Instructional System. In discussing what could be learned in this applied context, the advantages of using learning times in applied ATI research appeared to be twofold: (1) consistently found ATIs using learning times as criterion variables help isolate student characteristic/treatment matches that can improve training efficiency (e.g., we can assign students to treatments via adaptive decision rules that are based on learning time ATI findings) and (2) consistently found ATIs using learning times help advance our understanding of the kinds of students performing best with certain treatments and such theorizing can assist in future instructional design efforts (e.g., we can identify certain consistent student learning process/treatment component relationships to be considered in designing alternative treatments). From what we have said so far, then, the implication is clear: in an applied research environment, learning times are appropriate ATI outcome variables.

But what about the case of ATI research in a basic setting? Can we

then so easily dismiss the methodological concerns? From our example of applied ATI research in the context of the Air Force Advanced Instructional System we also addressed what could be learned from consistent ATI findings in an effort to examine the relevance of learning times as ATI outcome variables when one's primary goal is to advance theory--as it is in basic research. In an applied setting, we derived some theoretical speculations from the ATI findings which, at the very minimum, begin to give us some confidence in the face validity of these ATI findings. And, the consistency of the ATI findings across the criterion variables of learning times and criterion scores allowed some generalizations at the level of local theorizing, as discussed by Snow (1977). Is that enough, however, for us to say unequivocally that learning times are appropriate outcome variables for basic ATI research? We don't think so, particularly because of a number of issues that remain to be addressed.

The first remaining issue has to do with how one goes about defining and measuring aptitude variables. This issue is of utmost importance in all ATI research, but particularly ATI research conducted in a basic setting. As was mentioned in the introductory section of this paper, advancements have been and are continuing to be made in both the definition of cognitive processes and skills essential for learning, and in the theory and measurement of individual differences (e.g., Glaser, 1979; Snow, 1977; Wittrock, 1978). We have learned a great deal in these areas, but much is yet to be learned before the relationships between these aptitude variables and any criterion variable can be understood. And, because of the problems raised

by Cronbach and Snow (1977) with respect to (a) the error inherent in measures of learning rate, (b) the definition and measurement of what constitutes learning (or reaching criterion), and (c) the problem of controlling for learning-to-learn--it seems clear that in the area of basic ATI research it is particularly crucial that aptitudes be more clearly understood before learning times can be considered appropriate ATI outcome variables.

Related to this first issue is the issue of using any measures of performance outcomes that reflect the student's obtaining of a criterion. That is, in basic ATI research, one is primarily concerned with how or why learning occurs for some students with treatment A as opposed to treatment B. The concern is not one of searching for practical advantages (increased learning, decreased times) with one treatment versus another. In this situation, then, one can question whether any outcome variables from a criterion-referenced model are appropriate, or whether one might more appropriately use other kinds of variables. The criterion-referenced model was derived specifically to handle problems of implementing instruction in the applied educational environment, and as such, may not truly be suited to answering the questions posed by basic ATI research. In basic ATI research, then, one might more appropriately look at outcome variables such as types of concepts mastered or use of higher order cognitive strategies and processes--rather than the more general outcome variables useful in applied ATI research, i.e., times-to-criterion or criterion test scores.

Finally, in determining the appropriateness of learning times as outcome variables in both basic and applied ATI research contexts, the issue of using multiple outcome variables is relevant. In the example we presented, both times-to-criterion and criterion test scores were examined and consistent findings were summarized across these two outcome variables. This procedure appeared to us to be extremely helpful in raising our confidence about the validity of certain ATI findings. But, this was true because of the high correlation between our two outcome variables. Thus, one can begin to recognize the usefulness of using highly correlated multiple outcome variables in both basic and applied ATI research--insofar as the combined results can lead us to some consistent findings and generalizations about appropriate student/treatment matches. And perhaps, if variables which reflect learning times are used in conjunction with other types of highly correlated outcome variables in basic ATI research, the question of the appropriateness of learning times as outcome variables for basic ATI research might be answered more definitively.

To conclude, from our examination, it seems clear that learning times are appropriate ATI outcome variables in the applied research setting. In the applied setting, particularly self-paced environments, there are practical concerns with optimizing students' pace through the course, and thus the concern with providing adaptive instruction and identifying treatments that can increase learning efficiency for individual students. From our example, we learned that ATI research in such an applied setting resulted in consistent findings and the identification of treatment

components that could help maximize student efficiency and effectiveness. We also found that there were a number of theoretical speculations that could be derived--speculations which indicate the appropriateness of learning times as outcome variables in basic ATI research. But we were forced to give an equivocal answer to the question of whether learning times were truly appropriate for basic research, and we raised a number of issues to be dealt with before this question could be more definitively answered. From an examination of these issues, we are optimistic about the usefulness of at least exploring how learning time as an outcome variable in basic ATI research can assist in explaining some of the complex phenomena underlying individual differences.

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Table 1

ATI Summary Results

Part 1: Treatment Differences Only

Aptitude Variables	Basic Treatment		Enriched Treatment	
	Low*	High	Low	High
Reading Ability		o	o	
Trait Anxiety	o			o
Test Anxiety	o			o
	Management Condition Differences			
Trait Curiosity	NM	M	M	NM
State Curiosity	-	M	M	-

Part 2: Media Differences Only

Aptitude Variables	Audio-Visual		Illustrated Script	
	Low	High	Low	High
Reading Ability		o	o	
Rote Memory		o	o	
State Anxiety		o	o	
	Management Condition Differences			
Trait Anxiety	M	NM	NM	M
Trait Curiosity	NM	M	M	NM
State Curiosity	NM	M	M	NM
Higher Order Memory	NM	-	-	NM

NM = No Progress Management; M = Progress Management

* NOTE: The "Low," "High" designations refer to the aptitude levels of students performing best with a particular treatment.

Figure Captions

Figure 1. A working model for designing, evaluating, and implementing alternative instructional modules. (From Parkhurst & McCombs, 1979).

Figure 2. Basic experimental design for applied ATI study summary.

Figure 1.

A Working Model for Designing, Evaluating, and Implementing Alternative Instructional Modules (From Parkhurst & McCombs, 1979).

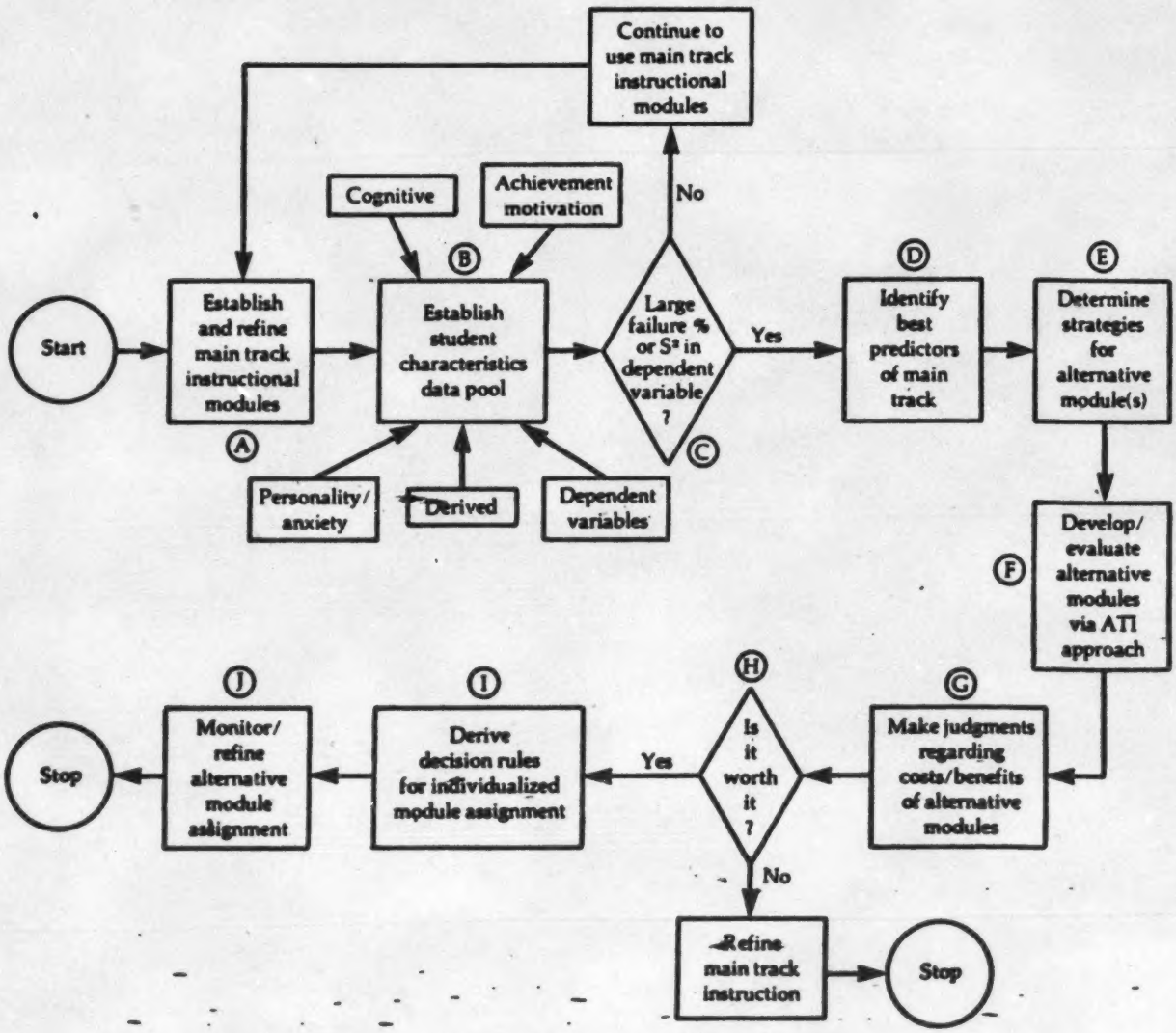

Figure 2

Basic Experimental Design for Applied ATI Study Summary*

Instructional Conditions	Types of Treatments			
	Multi-Track		Media Overlap	
	Basic	Enriched	Audio-Visual	Illustrated Script
No Progress Management				
Progress Management				

* Average number of cases per cell = 86.